ASSESSMENT OF RAINFALL VARIATION AND TRENDS IN CALABAR FOR THE PERIOD 1982-2011

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Abstract

The study examines the variation and trend of rainfall in Calabar for the period 1982-2011. Rainfall data for the study were collected from the Nigerian Meteorological Agency (NIMET),Margaret Ekpo International Airport, Calabar. Statistical techniques such as mean, standard deviation, standardized anomaly, coefficient of variation (CV) and Time Series Charts with Trend line analysis(smoothen with 5-years running mean)were used to depict the temporal variation of rainfall in Calabar. Furthermore, spectral analysis was also used to determine the periodicities of rainfall for Calabar using the 30 years (1982-2011) rainfall data. The result shows that the mean annual rainfall for the period of study over Calabar was found to be 2917.72 mm. The study also shows that 2011was the wettest year, while 1983 was revealed to be the most rainfall deficit year. When a 5 year running mean was put through the annual total rainfall series fluctuations involving increasing trend were most prominent in the periods 1986 – 2001 and 2006 – 2011. A fluctuation involving decreasing rainfall trend was only prominent in the period 2001 – 2006. Significant at 95%, the spectral analysis results gives dominant peaks at 3.9 years and 8.1 years, indicating the significant cycles of rainfall for the past 30 years in Calabar.

Keywords: Rainfall Variation and Trend, Spectral Analysis, Time Series Analysis, Rainfall Cycles, Calabar.

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INTRODUCTION

Rainfall is the total amount of rain that falls in a particular area within a certain period of time.Rainfall is one of the key climatic elements, because crops, animals and indeed humans derive their water resources largely from rainfall. It is considered as the main determinant of the types of crops that can be grown in the area and also the period of cultivation of such crops and the farming systems practiced. Also, being blessed with abundant freshwater swamps and watersheds, rainfall serves as a major means of recharge of these water sources in Calabar.

However, amidst these numerous benefits derived from rainfall, available statistics from Nigerian Meteorological agency (NIMET), Calabar shows mark variation of rainfall in the area over the past years, with its negative ills which pose great threats to human life, properties and urban agriculture within the city. Consequently, Calabar have suffered from severe floods in recent times. Indeed, the climate of the area has become highly unpredictable, making many people to wonder what has happened to the climate.For instance, available records of flood disaster occurrence and impact in the area reveals that in 2009, a total 1,567 buildings were being affected by flooding, displacing about 12,333 people and destroying properties worth millions of naira in Calabar. The records further reveal that in 2010, a total of 955 buildings were being affected by flood with the displacement of about 8,197 people and household properties worth millions of naira lost. In the same vein, the 2011 floods in Calabar, was devastating, because it overwhelmed the drains, which were designed to cope with only normal rainfall. The floods of 2011 resulted in major disasters with over 3,986 buildings in Calabar and its suburbs being overtaken by flood, rendering over 30,359 persons homeless and washing away several urban farmlands, disrupting socio-economic activities, displacing people, and causing damage to properties worth millions of naira (Cross River State Emergency Management Agency (SEMA), Calabar, Oct. 2012).

Invariably, with further significant variations in the rainfall characteristics of the area, it is important that scientific studies be undertaken so as to provide the society with accurate information on the real and potential impacts of extreme climatic variability, as well as, the mitigation and adaptation options available. At this time when the world is grappling with diverse environmental problems including global warming, ozone depletion, acid rain, killer hurricanes, destructive thunderstorms, droughts and major flood episodes, efforts at finding explanations to these problems should be of great importance, since the environmental, social and economic cost of managing extreme climatic variability is bound to be enormous from the standpoint of society and policy makers (Ekpoh, 2011).

Studies for changes in annual mean precipitation have been realized in several parts of the world. For instance, a steep decrease of the precipitation in 1970 has been identified in parts of Bulgaria and Romania (Adger , Hug , Brown, Conway , Hulme 2003). Several authors have analyzed hydro-meteorological time series in West Africa from Niger to Senegal (Le Barbe , Lebel , Tapsoba 2002). They pointed out the non-stationarity of the series and suggest a climatic jump down between 1965 and 1972, the majority of the shifts appearing between 1969 and 1970. Precipitation in the Great Plains of the United States of America also showed a significant change with an increase since the late 60´s, the last two decades being the wettest of the 20th century (Novotny and Sfefan (2007). The Brazilian Amazon basin precipitation records showed a shift near 1975, downward in the northern area and upward in the southern part (Marengo, 1999).

The Sahel is characterized by strong climatic variations and an irregular rainfall that ranges between 200mm and 600 mm with coefficients of variation ranging from 15 to 30% (Fox and Rockström, 2003; Kandji et al., 2006). According to IPCC, a rainfall decrease of 29-49% has been observed in the 1968-1997 period compared to the 1931-1960 baseline period within the Sahel region (McCarthy et al., 2001). The West Africa region has experienced a marked decline in rainfall from 15 to 30% depending on the area (Niasse, 2005). The trend was abruptly interrupted by a return of adequate rainfall conditions in 1994. This was considered to be the wettest year of the past 30 and was thought to perhaps indicate the end of the drought. Unfortunately, dry conditions returned after 1994 (McCarthy et al., 2001).

In the study of Ogolo and Adeyemi (2009), on the variations and trends of some meteorological parameters at Ibadan, they discovered that the downward trend in rainfall of 1988-1990 in Ibadan was interrupted by sharp increases between 1991 and 1993 to an above yearly average. This was followed by a drought year in 1994 where annual rainfall amount dropped to the minimum. Between 1995 and 1997, rainfall amount in this station follow an increasing trend. The years 1988, 1991, 1993, and 1995-1997 have been identified as years of above yearly average rainfall, while the years 1989, 1990, 1992 and 1994 are years of near and below yearly average rainfall.

This study therefore seeks to examine the variation and trends in rainfall over Calabar for the period 1982 to 2011 (30-year). The following objectives were employed in this work to achieve this aim such as:

(i) To examine the annual rainfall variation in Calabar for the period 1982-2011

(ii) To examine the trends in rainfall of the area for the period 1982-2011

(iii) To determine the periodicities of rainfall in Calabar for the period 1982-2011

MATERIALS AND METHOD

Study Area

Calabar is the capital of Cross River State. It is located at the Southern part of Cross River State as seen in Fig.1, Calabar is located between longitudes $8^0$17'00''E and $8^0$20'00''E latitudes $4^0$50'00''N and $5^0$10'00''N. Calabar metropolis comprises of Calabar Municipality and Calabar South Local Government Areas and covers an area of about 1,480 Sq km. As depicted in Fig.1 Calabar is sandwiched between the Great Kwa River to the East and the Calabar River to the West. The present of urban area is on the eastern bank of the Calabar River its growth to the south is hindered by the mangrove swamps.

Calabar falls within tropical equatorial (Af) climate with high temperature, high relative humidity and abundant annual rainfall (Oguntoyimbo, 1978; Inyang, 1980). Two major air masses affect the climate of Calabar as well as other contiguous locations in the West African region. The Tropical Maritime (mT) and the tropical continental (cT) air masses affect the climate in two distinct seasons. mT air prevails and influences its moisture characteristic while the cT air influences the dry season condition due to is desert source across the two air masses at the upper troposphere from east to west. This is called the Equatorial Esterlies (EE). The two air masses meet at the pressure front called Inter Tropical discontinuity (ITD) (Oguntoyimbo, 1978).

There have been a massive development and urban expansion in the area over the last 10 years. This development is not without repercussions on the natural environment as lands that were formally vegetated, used for agriculture and as habitat for biodiversity are now being used for residential, commercial and industrial purposes to accommodate the growing population and businesses.The loss of once vegetated land implies a corresponding alteration of the micro-climate of the area which in turn has great impact on the long term climatic averages of the area.

Types of Data and Source

The data required for this work was annual rainfall values over Calabar for the months January to December from 1982 to 2011. The data covers annual amounts for a period of 30 years (1982-2011).The data for this study was obtained mainly through secondary sources from the records section of the Nigerian Meteorological Agency, Margaret Ekpo international Airport, Calabar.

Techniques and Procedure

The purposive sampling technique was used for data collection. The measurement of rainfall is done by removing the funnel and emptying the collected rain in the bottle/container into a graduated cylinder with a 3.8 cm (1.5 inches) diameter. The reading is done at eye-level to an accuracy of 0.25 mm (0.01 inch).

Data analysis

Statistical and graphical tools in Microsoft Office Excel were primarily employed in the analysis and presentation of this study. These consist of the following:

(a) Time series with trend lines analysis of the annual rainfall values to illustrate the trend pattern in rainfall behavior.

(b) The spectral analysis applied in identifying the cycles of rainfall series in Calabar for the study period (1982-2011). The spectral analysis is used to analyze cycles of precipitation data. The power spectra of annual, seasonal and monthly anomalies were analyzed using the autocorrelation spectral analysis – ASA (Blackman and Tukey, 1958; WMO, 1966).The ASA is obtained by applying the discrete Fourier transform (DFT) algorithm to the correlation functions derived from the time series, taking as a smoothing function a Turkey- Hamming window (Padmanabhan, 1991). This was done using the spss software window.

(c) Standardized anomaly chart.

(d) Descriptive statistical analysis

(e) (i) Mean $(\bar{x}) = (\frac{\sum x}{N})$

Where; x = the variable

N = the number of years

(ii) Standard Deviation, S = $\sqrt{\frac{\sum(X-\bar{X})2}{N}}$

Where; x= the variable

x= the mean

N = the number of years

(f) Deviation scores X = x- x

(g) Coefficient of variation (CV)

RESULTSAND DISCUSSION

***Variation in Annual Rainfall in Calabar*:** The analysis of annual variation in rainfall of Calabar for the period 1982 to 2011 (30-years) is presented in table 1, below. The table shows the annual rainfall amount, standard deviation, standardized anomalies and coefficient of variation for rainfall in the area.

Table 1: Annual rainfall amount, standard deviation, standardized anomalies and coefficient of variation of rainfall in Calabar for the period 1982 – 2011.

S/N	Year	Annual Rainfall Amount (mm) (X)	Standard Deviation	Standardized Anomalies	Coefficient of Variation (CV)
1	1982	2815.60	-13.37	-0.30	3.5% *
2	1983	2328.20	-62.11	-1.38	20% *
3	1984	2499.10	-45.02	-1.00	14% *
4	1985	2963.80	1.45	0.03	1.6% **
5	1986	2610.50	-33.88	-0.75	10.5% *
6	1987	3008.60	5.93	0.13	3% **
7	1988	2723.20	-22.61	-0.50	7% *

8	1989	2765.60	-18.37	-0.41	5% *
9	1990	2729.10	-22.02	-0.49	6% *
10	1991	2661.90	-28.74	-0.64	9% *
11	1992	2896.40	-5.29	-0.12	1% *
12	1993	2511.30	-43.8	-0.97	14% *
13	1994	2904.60	-4.47	-0.10	1% *
14	1995	3749.70	80.04	1.77	26% **
15	1996	3215.60	26.63	0.59	8% **
16	1997	3492.40	54.31	1.20	17% **
17	1998	2811.50	-13.78	-0.31	4% *
18	1999	3004.40	5.51	0.12	3% **
19	2000	2807.20	-14.21	-0.32	4% *
20	2001	3202.00	25.27	0.56	8% **
21	2002	2813.20	-13.61	-0.30	4% *
22	2003	2807.40	-14.19	-0.31	4.5% *
23	2004	3094.00	14.47	0.32	5% **
24	2005	2707.70	-24.16	-0.54	9% *
25	2006	2492.10	-45.72	-1.01	17% *
26	2007	3428.20	47.89	1.06	17% **
27	2008	2886.80	-6.25	-0.14	1% *
28	2009	2527.10	-42.22	-0.94	13% *
29	2010	3071.70	12.24	0.27	4% **
30	2011	4002.80	105.35	2.33	37% **
$\sum$		**87531.7**			
$\bar{x}$		**2917.72**			

Source: Author's Analysis (2013)

From the table, in terms of actual annual rainfall totals, the wettest years in the period of record were 1985 (2963.10mm), 1987 (3008.60mm), 1995 (3749.70mm), 1996 (3215.60mm), 1997 (3492.40mm), 1999 (3004.40mm), 2001 (3202.00mm), 2004 (3094.00mm), 2007 (3428.20), 2010 (3071.70mm) and 2011 (4002.80mm). On the other hand, the driest years were

1983 (2328.20mm), 1984 (2499.10mm), 1993 (2511.30mm), 2006 (2492.10mm), and 2009 (2527.10mm).

Furthermore, in figure 1, annual total rainfall for Calabar was standardized and these standardized rainfall deviations were averaged for the period (1982-2011). From the results, years 1995, 1996, 1997, 2001, 2004, 2007, 2010 and 2011 are years with above average rainfall with 1995 and 2011 showing the highest positive deviation from the normal with coefficient determinant values 26% and 37% respectively. While 1983, 1984, 1986, 1988, 1989, 1990, 1991, 1993, 2005, 2006 and 2009 are years with rainfall below normal with 1983, 1993 and 2006 showing the highest negative deviation from the normal with coefficient determinant values of 20%, 14% and 17% respectively.

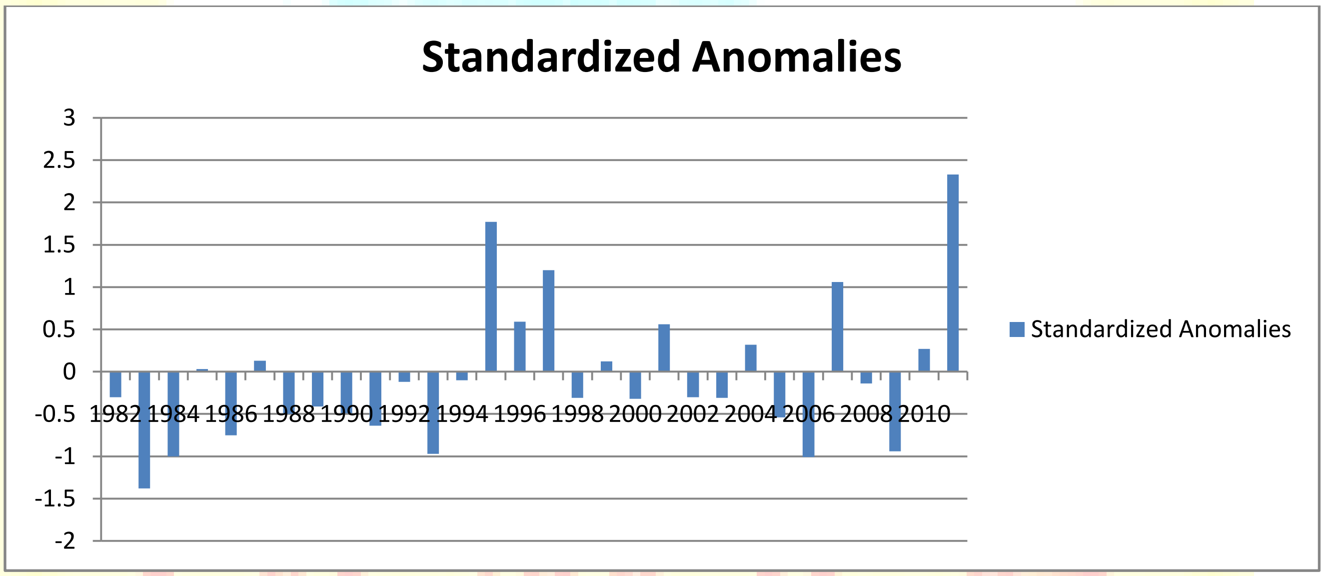

Fig. 1: Standardized rainfall anomalies of Calabar for the period 1982-2011

Annual Rainfall Trend in Calabar: Figure 2, shows the inter-annual rainfall variability over Calabar for the years under consideration, the trend suggests a general increase in rainfall values in recent times. Rainfall values for the years under consideration suggest values between 2886.80 and 4002.80mm. The inter-annual variability suggests a upward trend in the pattern when a trend line was fitted. When a 5 year running mean was put through the annual total rainfall series (figure 3), fluctuations involving increasing trend were most prominent in the periods 1986 – 2001 and 2006 – 2011. A fluctuation involving decreasing rainfall trend was only prominent in the period 2001 – 2006. The trend analysis however shows that the 30 years period (1982-2011) of rainfall in Calabar was characterized by an increasing rainfall in recent time, an indication that the climate of Calabar may be becoming wetter.

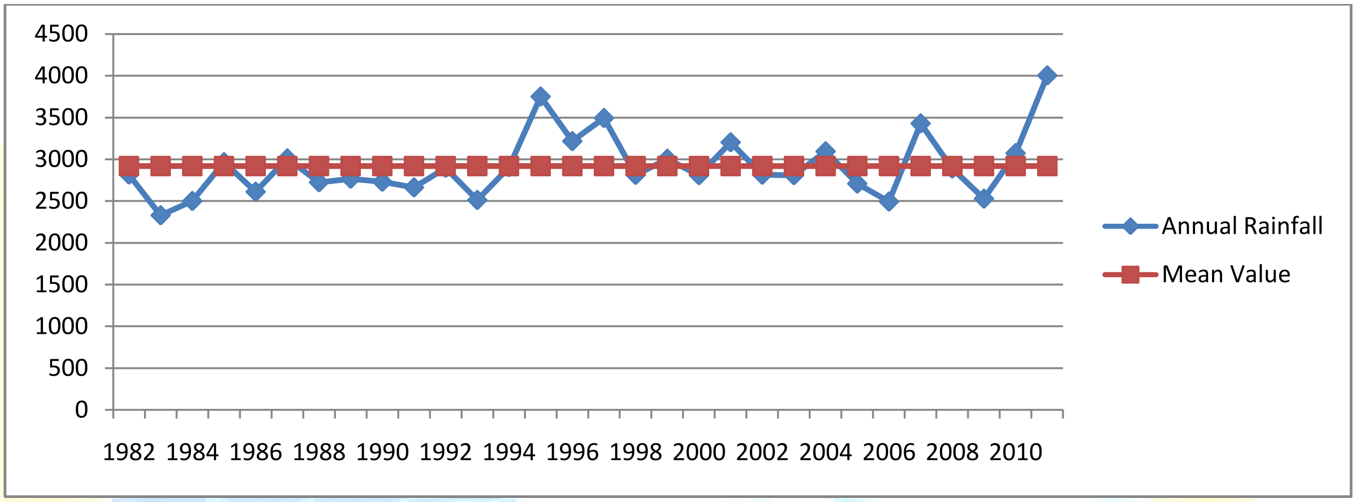

Figure 2: Trend in annual rainfall for Calabar from 1982-2011

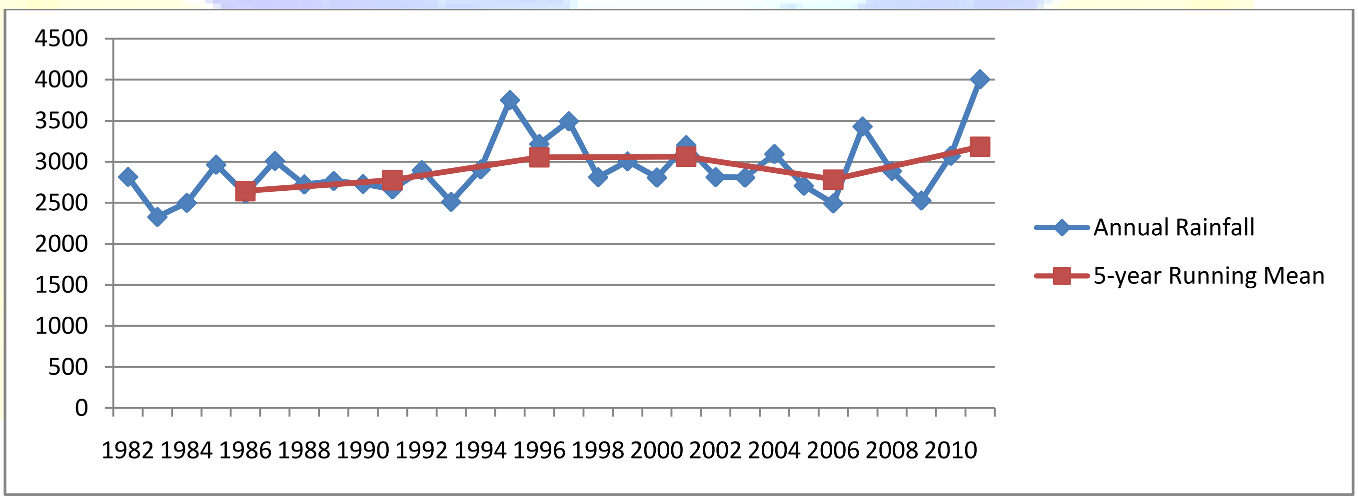

Figure 3: Trend in annual rainfall for Calabar smoothen with 5-years running mean

Rainfall Cycles in Calabar:Furthermore, the trend in rainfall series of the area was explained using the Autocorrelation Spectral Analysis (ASA). From figure 4, the plot of the periodogram shows a sequence of peaks that stand out from the background noise, with the lowest frequency peak at a frequency of just less than 0.2. The univariate statistics table (Appendix) contains points that are used to plot the periodogram. From the table, it can be observed that for frequencies between 0.1 and 0.2, the largest value in the periodogram column occurs at a frequency of 0.1333. This confirms the identification of the lowest frequency peak with an annual periodic component.

The remaining peaks were being analyzed with the spectral density function, which simply is a smoothed version of the periodogram (figure 5). This aided to provide a means of eliminating the background noise from the periodogram allowing the underlying structure to be more clearly isolated. From the results, the second highest peak was observed for frequencies between 0.2 and 0.3 and the largest value within these frequencies occurred at a frequency of 0.3000. Significant at 95%, the results gives dominant peaks at 3.9 years and 8.1 years for the 30 years rainfall data.

The result shows that rainfall in Calabar is primarily characterized by a multiple, non-symmetric cycle of anomalies with varying magnitudes. These observations confirm earlier findings by Bunting *et al*. (1976) and (Kalu, 1987). However, these cycles could vary depending on the length of the rainfall data used for the analysis.

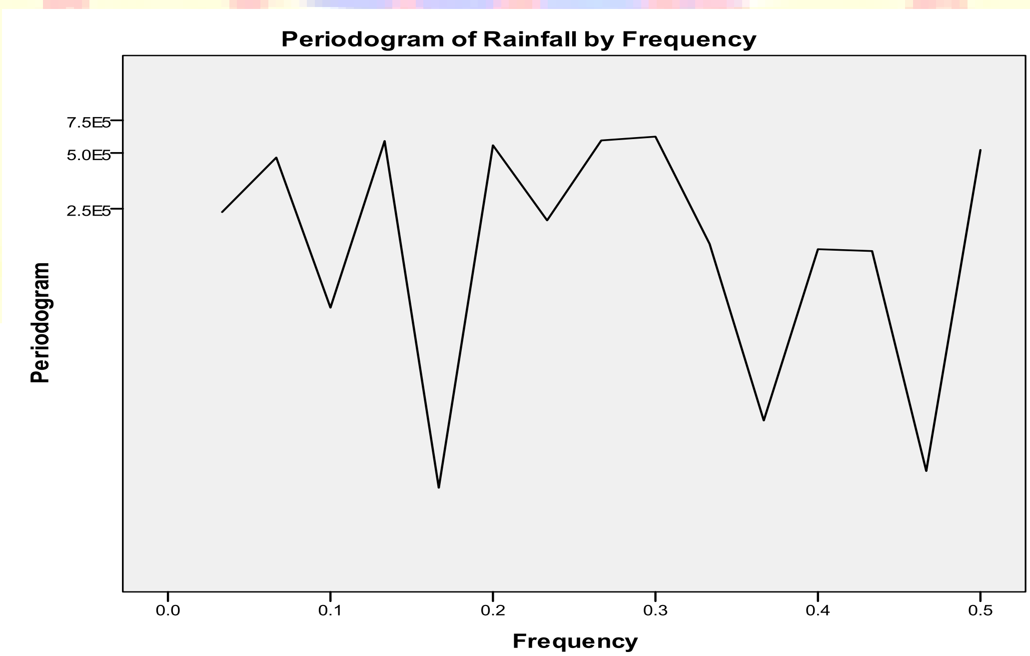

Figure 4: Periodogram of annual rainfall for Calabar for the period 1982-2011

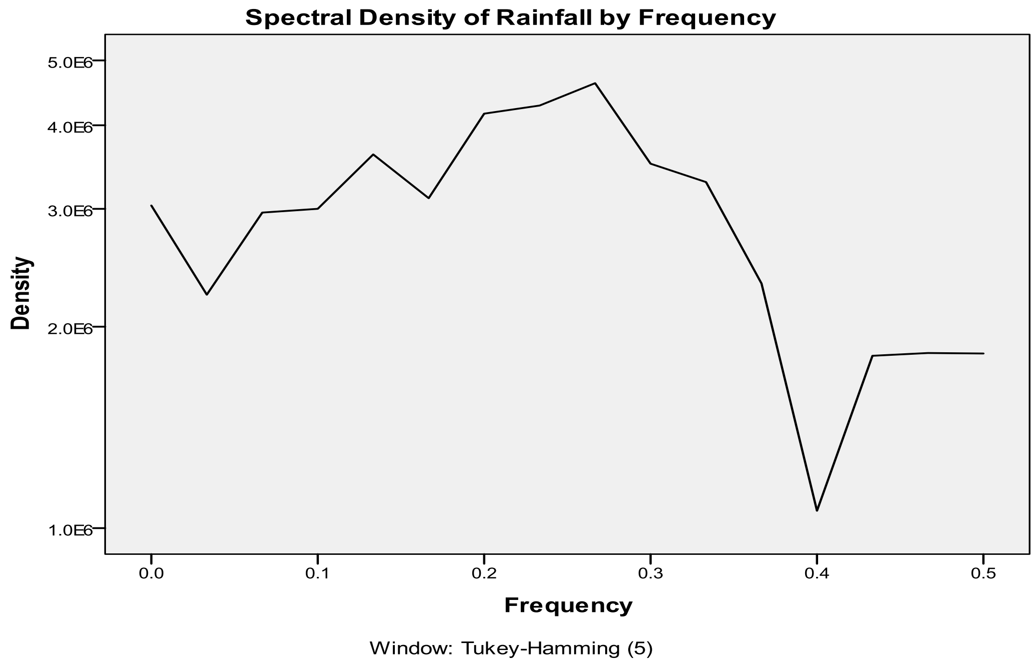

Figure 5: Spectral density of annual rainfall for Calabar for the period 1982-2011

CONCLUSION/RECOMMENDATIONS

The evaluation of annual rainfall amount in Calabar for the period 1982 to 2011 (30 years) demonstrates the existence of marked variations and trends in the rainfall characteristics of the area. The result reflects a continuous inconsistency in the pattern of rainfall in Calabar with an increasing trend, which clearly indicates that the climate of Calabar is becoming wetter with cycles of 3.9 and 8.1 years. This increasing rainfall trend has implication on flooding within the city. Therefore, timely observation and forecasts of rainfall onset, duration (length of rainy season) and cessation are useful in addressing the persistence problem of flooding within the city.

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